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(54) Title: REDUCING AGENT FOR REDUCTIVE ALKYLATION OF GLYCOPEPTIDE ANTIBIOTICS (57) Abstract This invention is concerned with improved processes for reductive alkylation of glycopeptide antibiotics, the improvement residing in employing pyridine-borane as reducing agent.		

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REDUCING AGENT FOR
REDUCTIVE ALKYLATION OF GLYCOPEPTIDE ANTIBIOTICS

The present invention is directed to improved methods
5 for reductively alkylating glycopeptide antibiotics, the
improvement residing in the use of pyridine-borane complex
as the reducing agent.

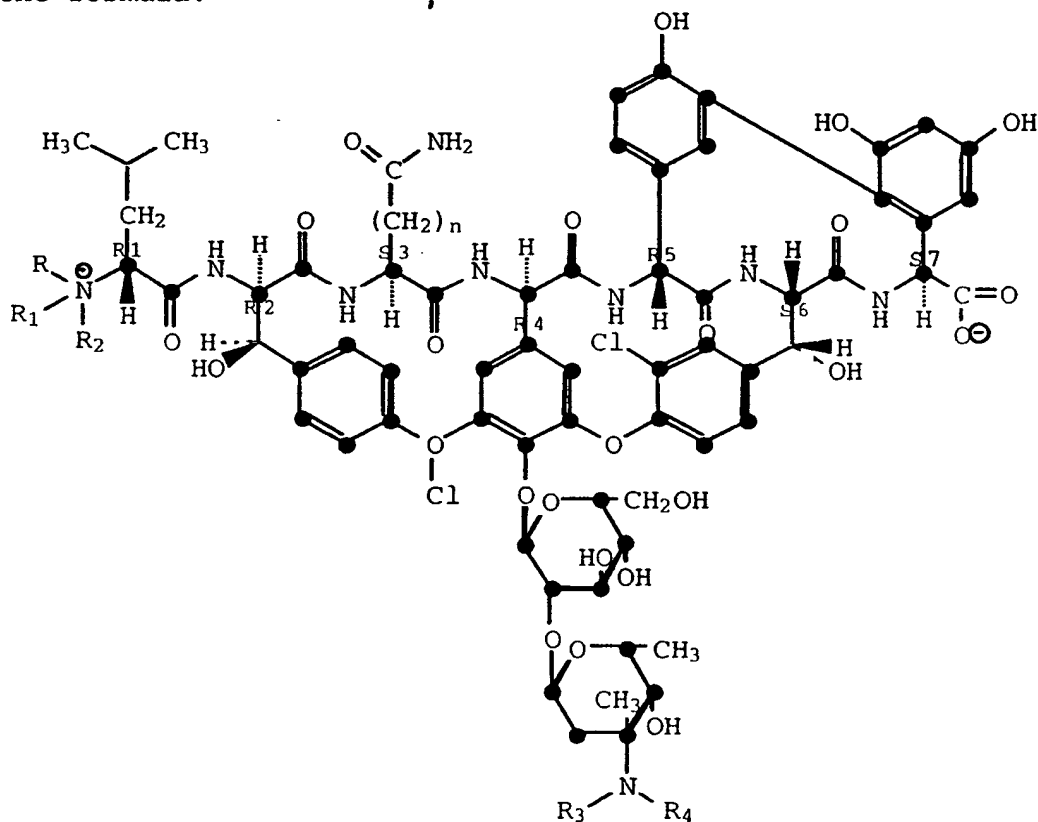
The present invention relates to reductive alkylation
10 of glycopeptide antibiotics.

The glycopeptide antibiotics are a large class of
substances either produced by microorganisms, or produced by
microorganisms and thereafter subsequently modified in part.
Two of these, vancomycin and teicoplanin, are sold as
15 antibacterial products, but many others have been discovered
and are being considered for development, especially since
the emergence in the late 1980s of resistance to various
antibiotics, including the glycopeptides themselves. The
entire class of glycopeptide antibiotics is well described
20 in "Glycopeptide Antibiotics", edited by Ramakrishnan
Nagarajan (Marcel Dekker, Inc., New York, 1994). Among the
more recently discovered glycopeptides are those known as
A82846A (also called ereomomycin), A82846B (also known as
chloroorienticin A), A82846C (also known as orienticin C),
25 and orienticin A. The present invention is preferred for
use with vancomycin type glycopeptide antibiotics, including
vancomycin, A82846A, A82846B, A82846C, and orienticin A.
The invention is especially preferred for use with A82846B.

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Many modifications of naturally-occurring glycopeptides have been made. Among the modifications are reductive alkylations of reactive amine(s) in glycopeptides. See, for example, U.S. 4,698,327 describing reductive alkylations of vancomycin, and EPO 435 503 A1 and EPO 667 353 A1, both of which describe reductive alkylations of a variety of glycopeptides including vancomycin, A82846A, A82846B, A82846C, and orienticin A. These references describe reductive alkylations which introduce into the parent glycopeptides a great variety of alkyl groups.

4,698,327 describes alkylated vancomycin compounds of the formula:



wherein

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R is hydrogen or methyl;

n is 1 or 2; and

R₁ is hydrogen or methyl;

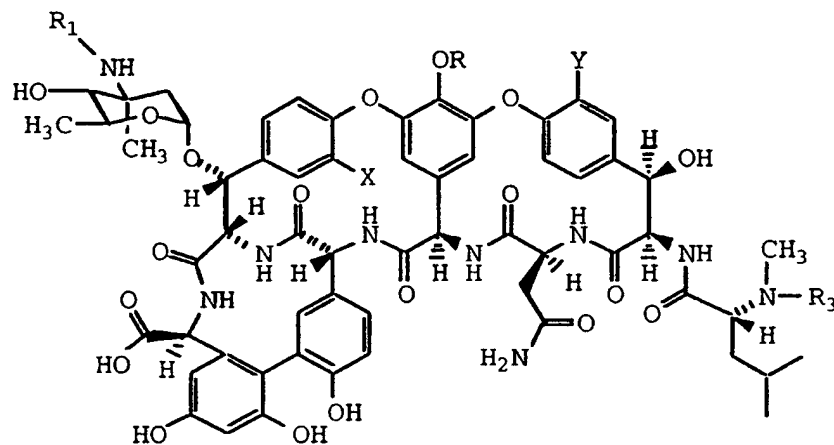
R₂ and R₃, independently, are hydrogen or a group of
5 the formula: R₆R₇CH-;

R₆ and R₇ are independently R₅, R₅-(C₁-C₅-alkyl) or R₅-(C₂-C₅-alkenyl);

R₅ is hydrogen, C₁-C₁₀-alkyl, C₂-C₁₀-alkenyl, C₁-C₄
alkoxy, C₃-C₁₀-cycloalkyl, C₅-C₁₂-cycloalkenyl, phenyl,
10 naphthyl, indenyl, tetralinyl, decalinyl, adamantyl, a
monocyclic heterocyclic ring system comprising 3 to 8 atoms
in the ring or a bicyclic heterocyclic ring system
comprising 6 to 11 atoms, provided that at least one atom of
the ring system is carbon and at least one atom of the ring
15 system is a heteroatom selected from O, N, and S, and R₅ may
be substituted with one or more hydroxy, nitro, C₁-C₁₀-
alkoxy, C₁-C₁₀-alkyl, phenyl, C₁-C₆-alkylthio, nitrile,
halo, C₂-C₄-acylamino, amino, C₁-C₄-dialkylamino groups; and
R₄ is hydrogen, provided that: (1) at least one of R₂ and
20 R₃ must be other than hydrogen; (2) when n is 2, R must be
hydrogen; (3) when R is methyl and R₃ is hydrogen, R₂ cannot
be methyl and (4) when R and R₁ are both methyl, then R₂ is
hydrogen or methyl and n is 1.

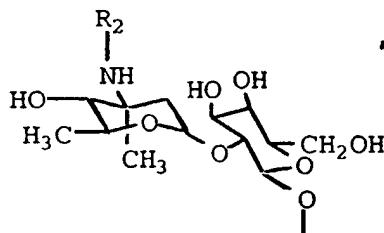
EPO 435 503 A1 is directed to alkylated and acylated
25 glycopeptides of the formula:

-4-



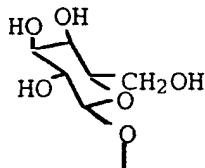
wherein:

R is hydrogen or a (4-epi-vancosaminyl)-O-glucosyl group of formula



5

or the glucosyl group of formula

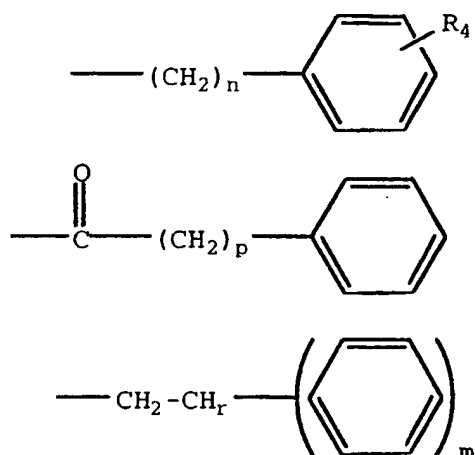


X is hydrogen or chloro;

Y is hydrogen or chloro;

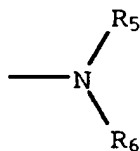
10 R₁, R₂, and R₃ are independently hydrogen; C₁-C₁₂ alkyl; C₂-C₉ alkanoyl; or a group of formula

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n is 1 to 3;

R₄ is hydrogen, halo, C₁-C₈ alkyl, C₁-C₈ alkoxy, or a group of formula



5

R₅ and R₆ are independently hydrogen or C₁-C₃ alkyl;

p is 0 to 2;

m is 2 or 3, and r = 3 - m; provided that, where R is a (4-epi-vancosaminyloxy)-glucosyl group, R₁, R₂, and R₃ are not all hydrogen, and where R is hydrogen or a glucosyl group, R₁ and R₃ are not both hydrogen.

10

Where R is (4-epi-vancosaminyloxy)-glucosyl, the glycopeptides so defined are

X = H, Y = Cl, A82846A

15

X = Y = Cl, A82846B

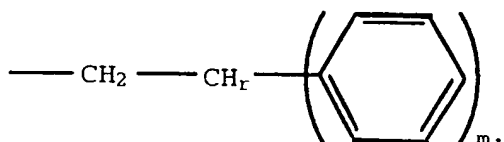
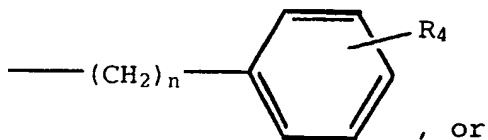
X = Y = H, A82846C

X = Cl, Y = H, orienticin A.

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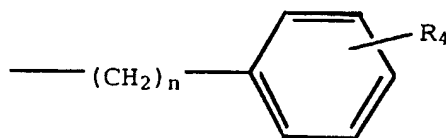
Thus, EPO 435 503 A1 describes alkyl derivatives of A82846A, A82846B, A82846C, and orienticin A wherein the alkyl group is

—C₁—C₁₂ alkyl,



5

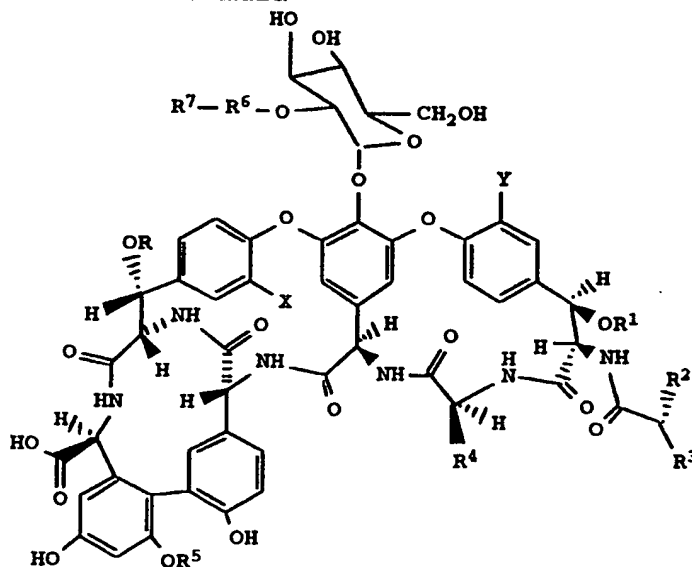
Preferred groups are C₈-C₁₂ alkyl and groups of the formula



wherein R₄ is hydrogen, halo, C₁-C₈ alkyl, or C₁-C₈ alkoxy.

EPO 667 353 A1 describes alkylated glycopeptide

10 antibiotics of the formula



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wherein:

X and Y are each independently hydrogen or chloro;

R is hydrogen, 4-*epi*-vancosaminy, actinosaminy, or ristosaminy;

5 R¹ is hydrogen, or mannose;

R² is -NH₂, -NHCH₃, or -N(CH₃)₂;

R³ is -CH₂CH(CH₃)₂, [*p*-OH, *m*-Cl]phenyl, *p*-rhamnose-phenyl, or [*p*-rhamnose-galactose]phenyl, [*p*-galactose-galactose]phenyl, [*p*-CH₃O-rhamnose]phenyl;

10 R⁴ is -CH₂(CO)NH₂, benzyl, [*p*-OH]phenyl, or [*p*-OH, *m*-Cl]phenyl;

R⁵ is hydrogen, or mannose;

R⁶ is vancosaminy, 4-*epi*-vancosaminy, L-actinosaminy, L-ristosaminy, or L-actinosaminy;

15 R⁷ is (C₂-C₁₆)alkenyl, (C₂-C₁₂)alkynyl, (C₁-C₁₂ alkyl)-R₈, (C₁-C₁₂ alkyl)-halo, (C₂-C₆ alkenyl)-R₈, (C₂-C₆ alkynyl)-R₈, (C₁-C₁₂ alkyl)-O-R₈, and is attached to the amino group of R⁶;

R⁸ is selected from the group consisting of:

20 a) multicyclic aryl unsubstituted or substituted with one or more substituents independently selected from the group consisting of:

(i) hydroxy,

(ii) halo,

25 (iii) nitro,

(iv) (C₁-C₆)alkyl,

(v) (C₂-C₆)alkenyl,

(vi) (C₂-C₆)alkynyl,

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- (vii) (C₁-C₆)alkoxy,
(viii) halo-(C₁-C₆)alkyl,
(ix) halo-(C₁-C₆)alkoxy,
(x) carbo-(C₁-C₆)alkoxy,
5 (xi) carbobenzyloxy,
(xii) carbobenzyloxy substituted with (C₁-C₆)alkyl,
(C₁-C₆)alkoxy, halo, or nitro,
(xiii) a group of the formula -S(O)_{n'}-R⁹, wherein n' is
0-2 and R⁹ is (C₁-C₆)alkyl, phenyl, or phenyl substituted
10 with (C₁-C₆)alkyl, (C₁-C₆)alkoxy, halo, or nitro, and
(xiv) a group of the formula -C(O)N(R¹⁰)₂ wherein each
R¹⁰ substituent is independently hydrogen, (C₁-C₆)-alkyl,
(C₁-C₆)-alkoxy, phenyl, or phenyl substituted with (C₁-C₆)-
alkyl, (C₁-C₆)-alkoxy, halo, or nitro;
15 b) heteroaryl unsubstituted or substituted with one or
more substituents independently selected from the group
consisting of:
(i) halo,
(ii) (C₁-C₆)alkyl,
20 (iii) (C₁-C₆)alkoxy,
(iv) halo-(C₁-C₆)alkyl,
(v) halo-(C₁-C₆)alkoxy,
(vi) phenyl,
(vii) thiophenyl,
25 (viii) phenyl substituted with halo, (C₁-C₆)alkyl, (C₂-
C₆)alkenyl, (C₂-C₆)alkynyl, (C₁-C₆)alkoxy, or nitro,
(ix) carbo-(C₁-C₆)alkoxy,

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(x) carbobenzyloxy,

(xi) carbobenzyloxy substituted with (C₁-C₆)alkyl, (C₁-C₆) alkoxy, halo, or nitro,(xii) a group of the formula -S(O)_n-R⁹, as defined

5 above,

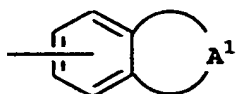
(xiii) a group of the formula -C(O)N(R¹⁰)₂ as defined

above, and

(xiv) thienyl;

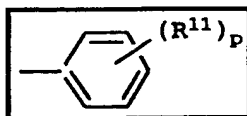
c) a group of the formula:

10



wherein A¹ is -OC(A²)₂-C(A²)₂-O-, -O-C(A²)₂-O-, -C(A²)₂-O-, or -C(A²)₂-C(A²)₂-C(A²)₂-C(A²)₂-, and each A² substituent
 15 is independently selected from hydrogen, (C₁-C₆)-alkyl, (C₁-C₆)alkoxy, and (C₄-C₁₀)cycloalkyl;

d) a group of the formula:



20

wherein p is from 1 to 5; and

R¹¹ is independently selected from the group consisting
 of:

(i) hydrogen,

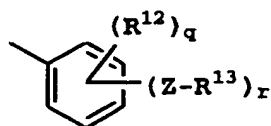
25 (ii) nitro,

(iii) hydroxy,

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- (iv) halo,
(v) (C₁-C₈)alkyl,
(vi) (C₁-C₈)alkoxy,
(vii) (C₉-C₁₂)alkyl,
5 (viii) (C₂-C₉)alkynyl,
(ix) (C₉-C₁₂)alkoxy,
(x) (C₁-C₃)alkoxy substituted with (C₁-C₃)alkoxy,
hydroxy, halo(C₁-C₃)alkoxy, or (C₁-C₄)alkylthio,
(xi) (C₂-C₅)alkenyloxy,
10 (xii) (C₂-C₁₃)alkynyloxy
(xiii) halo-(C₁-C₆)alkyl,
(xiv) halo-(C₁-C₆)alkoxy,
(xv) (C₂-C₆)alkylthio,
(xvi) (C₂-C₁₀)alkanoyloxy,
15 (xvii) carboxy-(C₂-C₄)alkenyl,
(xviii) (C₁-C₃)alkylsulfonyloxy,
(xix) carboxy-(C₁-C₃)alkyl,
(xx) N-[di(C₁-C₃)-alkyl]amino-(C₁-C₃)alkoxy,
(xxi) cyano-(C₁-C₆)alkoxy, and
20 (xxii) diphenyl-(C₁-C₆)alkyl,
with the proviso that when R¹¹ is (C₁-C₈)alkyl, (C₁-
C₈)alkoxy, or halo, p must be greater or equal to 2, or when
R⁷ is (C₁-C₃ alkyl)-R⁸ then R¹¹ is not hydrogen, (C₁-
C₈)alkyl, (C₁-C₈)alkoxy, or halo;
25 e) a group of the formula:

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wherein q is 0 to 4;

R¹² is independently selected from the group consisting

5 of:

- (i) halo,
- (ii) nitro,
- (iii) (C₁-C₆)alkyl,
- (iv) (C₁-C₆)alkoxy,
- 10 (v) halo-(C₁-C₆)alkyl,
- (vi) halo-(C₁-C₆)alkoxy, and
- (vii) hydroxy, and
- (viii) (C₁-C₆)thioalkyl;

r is 1 to 5; provided that the sum of q and r is no

15 greater than 5;

Z is selected from the group consisting of:

- (i) a single bond,
- (ii) divalent (C₁-C₆)alkyl unsubstituted or
- substituted with hydroxy, (C₁-C₆)alkyl, or (C₁-C₆)alkoxy,
- 20 (iii) divalent (C₂-C₆)alkenyl,
- (iv) divalent (C₂-C₆)alkynyl, or
- (v) a group of the formula -(C(R¹⁴)₂)_s-R¹⁵- or -
- R¹⁵-(C(R¹⁴)₂)_s-, wherein s is 0-6; wherein each R¹⁴

substituent is independently selected from hydrogen, (C₁-

25 C₆)-alkyl, or (C₄-C₁₀) cycloalkyl; and R¹⁵ is selected from -

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O-, -S-, -SO-, -SO₂-, -SO₂-O-, -C(O)-, -OC(O)-, -C(O)O-, -NH-, -N(C₁-C₆ alkyl)-, and -C(O)NH-, -NHC(O)-, N=N;

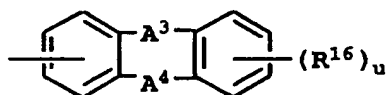
R¹³ is independently selected from the group consisting of:

- 5 (i) (C₄-C₁₀)heterocyclyl,
(ii) heteroaryl,
(iii) (C₄-C₁₀)cycloalkyl unsubstituted or substituted with (C₁-C₆)alkyl, or
(iv) phenyl unsubstituted or substituted with 1 to
10 5 substituents independently selected from: halo, hydroxy, nitro, (C₁-C₁₀) alkyl, (C₁-C₁₀)alkoxy, halo-(C₁-C₃)alkoxy, halo-(C₁-C₃)alkyl, (C₁-C₃)alkoxyphenyl, phenyl, phenyl-(C₁-C₃)alkyl, (C₁-C₆)alkoxyphenyl, phenyl-(C₂-C₃)alkynyl, and (C₁-C₆)alkylphenyl;
- 15 f) (C₄-C₁₀)cycloalkyl unsubstituted or substituted with one or more substituents independently selected from the group consisting of:
- (i) (C₁-C₆)alkyl,
(ii) (C₁-C₆)alkoxy,
20 (iii) (C₂-C₆)alkenyl,
(iv) (C₂-C₆)alkynyl,
(v) (C₄-C₁₀)cycloalkyl,
(vi) phenyl,
(vii) phenylthio,
25 (viii) phenyl substituted by nitro, halo, (C₁-C₆)alkanoyloxy, or carbocycloalkoxy, and

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(ix) a group represented by the formula $-Z-R^{13}$ wherein Z and R^{13} are as defined above; and

g) a group of the formula:



5

wherein

A^3 and A^4 are each independently selected from

(i) a bond,

10 (ii) $-O-$,

(iii) $-S(O)_t-$, wherein t is 0 to 2,

(iv) $-C(R^{17})_2-$, wherein each R^{17} substituent is independently selected from hydrogen, (C_1-C_6) alkyl, hydroxy, (C_1-C_6) alkyl, (C_1-C_6) alkoxy, or both R^{17} substituents taken

15 together are O,

(v) $-N(R^{18})_2-$, wherein each R^{18} substituent is independently selected from hydrogen; (C_1-C_6) alkyl; (C_2-C_6) alkenyl; (C_2-C_6) alkynyl; (C_4-C_{10}) cycloalkyl; phenyl; phenyl substituted by nitro, halo, (C_1-C_6) alkanoyloxy; or
20 both R^{18} substituents taken together are (C_4-C_{10}) cycloalkyl;

R^{16} is R^{12} or R^{13} as defined above; and

u is 0-4.

In this reference, preferred glycopeptide antibiotics are A82846A, A82846B, A82846C, and orienticin A; preferred
25 alkyls are those wherein R^7 is CH_2-R_8 ; and preferred R^8 moieties are those defined as groups "(d)" and "(e)".

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The present invention can be utilized to make the alkylated glycopeptides described in these references. Preferred alkylated glycopeptides which can be prepared by the present process include the following:

- 5 N^4 -n-octylA82846B
- N^4 -n-decylA82846B
- N^4 -benzylA82846B
- N^4 -(p-chlorobenzyl)A82846B
- N^4 -(p-bromobenzyl)A82846B
- 10 N^4 -(p-propylbenzyl)A82846B
- N^4 -(p-isopropylbenzyl)A82846B
- N^4 -(p-butylbenzyl)A82846B
- N^4 -(p-isobutylbenzyl)A82846B
- N^4 -(p-pentylbenzyl)A82846B
- 15 N^4 -(p-isoheptylbenzyl)A82846B
- N^4 -(p-octylbenzyl)A82846B
- N^4 -(p-propoxybenzyl)A82846B
- N^4 -(p-isopropoxybenzyl)A82846B
- N^4 -(p-butoxybenzyl)A82846B
- 20 N^4 -(p-tert-butoxybenzyl)A82846B
- N^4 -(p-pentyloxybenzyl)A82846B
- N^4 -(p-hexyloxybenzyl)A82846B
- N^4 -(o-hexyloxybenzyl)A82846B
- N^4 -(p-heptyloxybenzyl)A82846B
- 25 N^4 -(p-octyloxybenzyl)A82846B
- N^4 -phenethylA82846B
- N^4 -(4-phenylbenzyl)A82846B
- N^4 -(4-(4-chlorophenyl)benzyl)A82846B

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N⁴-(4-(4-methylbenzyloxy)benzyl)A82846B

N⁴-(4-(4-ethylbenzyloxy)benzyl)A82846B

N⁴-(4-(4-chlorophenethyl)benzyl)A82846B

N⁴-(4-(2-(4-methoxyphenyl)ethynyl)benzyl)A82846B.

5 The references noted above describe the reductive alkylation as comprising a first step, in which the glycopeptide is reacted with the respective aldehyde or ketone to form a Schiff's base, which in a second step is reduced to the desired alkylated product. In one variation
10 of this procedure, EPO 667 353 A1 describes a process in which the reducing agent is added simultaneously with the glycopeptide and aldehyde or ketone.

 The references suggest a strong preference for sodium cyanoborohydride as reducing agent. While sodium
15 cyanoborohydride is a successful reagent for small scale use, its use in large scale production is less satisfactory. This is due to safety and environmental issues posed by the cyanide ion. Accordingly, sodium cyanoborohydride is less than an ideal reducing agent for larger scale reactions.

20 Reducing agents are legion, but many are unsatisfactory for the glycopeptides. One of the many reducing agents known for use in reductive alkylations is pyridine·borane (see J. Chem Soc., Perkin Trans. 1 (1984), pages 717-720, which is incorporated herein by reference). It has now been
25 discovered that pyridine·borane is a uniquely acceptable reagent for alkylative reductions on glycopeptides, while presenting no safety or environmental hazards as is the case

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with sodium cyanoborohydride. Furthermore, in a preferred embodiment, it has been discovered that portionwise addition of the pyridine-borane increases yields.

Thus, the present invention is directed to an improved
5 process for reductively alkylating an amine-containing glycopeptide antibiotic, which process comprises reacting the glycopeptide antibiotic with an aldehyde or ketone in the presence of a reducing agent, wherein the improvement comprises employing pyridine-borane as reducing agent. In a
10 preferred embodiment, the glycopeptide antibiotic, aldehyde or ketone, and a portion of the reducing agent are mixed together at the same time, and one or more additional portions of reducing agent are added thereafter.

In carrying out the present invention, standard
15 conditions for reductive alkylations of glycopeptides are employed, other than the identity of the reducing agent and the preference for its portionwise addition. Thus, the glycopeptide and aldehyde or ketone are initially dissolved in a solvent which is at least predominantly methanol, and
20 which is preferably only methanol. If only these reagents are supplied, some small amount of Schiff's base is produced, but the reaction equilibrium does not favor complete production of the Schiff's base. Addition of reducing agent shifts the equilibrium as Schiff's base is
25 converted to alkylated product. As noted, EPO 667 353 A1 teaches a preference for simultaneous addition of the reducing agent with the glycopeptide antibiotic and aldehyde or ketone. Thus, in the present invention, the

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glycopeptide, aldehyde or ketone, and pyridine-borane are added at essentially the same time.

Further, it has been discovered that when employing pyridine-borane as reducing agent, even simultaneous
5 addition of glycopeptide antibiotic, aldehyde or ketone, and reducing agent leads to only modest yields and that such yields can be increased by portionwise addition of the pyridine-borane, with no more than a portion being added initially to the glycopeptide antibiotic and the aldehyde or
10 ketone.

The exact number and timing of portions is not critical. The reaction is generally conducted over a period of time from 4 to 48 hours and preferably from 6 to 24 hours. In the preferred practice of the present invention,
15 a first portion of pyridine-borane is added with the glycopeptide antibiotic and aldehyde or ketone, and the remainder of the pyridine-borane is added in one, two, or more subsequent portions. The ideal sequence of pyridine-borane addition appears to be five portions at 2 to
20 4 hour intervals (counting the initial addition as the first of the five). Devices can be employed to provide a continuous delivery of the pyridine-borane.

In another preferred embodiment of the invention, a source of soluble copper is supplied to the reaction
25 mixture, initially converting the glycopeptide to a copper complex, which becomes the reactive entity. The use of copper confers regioselectivity of reaction in those glycopeptides having multiple reactive amines. For example,

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in A82846B, the use of copper minimizes reaction on the N¹ (leucine) site and on the N⁶ (monosaccharide) site, thereby providing higher yields of the product monoalkylated on the N⁴ (disaccharide) amine.

5 The identity of the copper source is not critical, so long as it is at least partially soluble and does not negatively impact the pH. Suitable copper salts are cupric acetate, cupric trifluoroacetate, cupric cyclohexanebutyrate, cupric 2-ethylhexanoate, cuprous
10 chloride, cupric chloride, and cupric bromide. A preferred source of copper is copper (II) acetate, most conveniently employed as the hydrate.

The reaction should be conducted at a pH of 6-8, and preferably at a pH of 6.3-7.0.

15 The amounts of reactants and reagents to be employed are not critical; amounts to maximize the yield of product will vary somewhat with the identity of the reactants. The reaction consumes the glycopeptide antibiotic and the aldehyde or ketone in equimolar amounts. A slight excess of
20 the aldehyde or ketone, e.g., 1.3 to 1.7:1, is preferred. The amount of the glycopeptide antibiotic to be used must be corrected for its purity. The reaction consumes an equimolar amount of the pyridine-borane. A slight excess is preferable. The amount of soluble copper, if used, is
25 important. The process first results in the formation of a 1:1 copper complex with the glycopeptide antibiotic. Therefore, the copper is preferably present in an amount

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approximately equimolar with the glycopeptide antibiotic. However, amounts exceeding one molar equivalent are undesirable because excess copper decomposes the pyridine-borane.

5 Summarizing the foregoing, the ideal amounts to be employed are a ratio of:
glycopeptide:aldehyde or ketone:reducing agent:copper salt
of:

1:1.3 to 1.7:1.5:0.9 to 1.

10 The concentration of the reactants in the solvent has some bearing on the process. Methanol volume relative to mass of glycopeptide antibiotic can vary from 50:1 to 500:1; a 100:1 dilution appears to be a useful, practical ratio, although higher dilutions may give slightly higher yields.

15 The temperature at which the process is carried out is important. Reaction mixtures in methanol boil at about 67°C., thereby setting the maximum temperature when employing straight methanol as the solvent. Higher temperatures are of course possible when employing mixtures
20 of methanol or when operating under pressure. Lower temperatures can be tolerated, but preferably not lower than about 45°C. The ideal conditions depend upon whether or not copper is employed in the reaction. When copper is not added, it is preferred to conduct the reaction in straight
25 methanol at temperatures of about 58-67°C. When employing copper, it is important to conduct the reaction at slightly lower temperatures of about 58-63°C; again, straight methanol is preferred.

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Upon the completion of the reaction, the reaction mixture is preferably quenched, as by the addition of sodium borohydride. This reagent consumes residual aldehyde or ketone and thereby prevents further undesired reactions.

5 The product is isolated from the reaction mixture in conventional manner. When copper has been employed, the product is isolated from the reaction mixture as a copper complex of the alkylated glycopeptide. Isolation is achieved by concentration of the reaction mixture and
10 precipitation of the complex by addition of an antisolvent such as ethyl acetate, acetone, 1-propanal, isopropyl alcohol, or preferably acetonitrile. The complex can be broken by aqueous treatment at pH 2-4, freeing the simple alkylated glycopeptide product, which can, if desired, be
15 purified in conventional manner.

The following examples illustrate the present invention and will enable those skilled in the art to practice the same.

EXAMPLE 1

20

A82846B (0.50 g, 84.3% potency, 0.42 mg, 0.26 mmol) was stirred in 50 mL methanol and 4'-chloro-4-biphenylcarboxaldehyde (72 mg, 0.33 mmol) and pyridine-borane complex (0.033 mL, 0.33 mmol) were added.
25 The mixture was heated at reflux for 6 hours before being cooled to ambient temperature. HPLC analysis of a reaction aliquot afforded a yield of 0.25 g (53.2%) of N⁴-(4-(4-chlorophenyl)benzyl)A82846B.

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EXAMPLE 2

(portionwise addition of pyridine·borane)

A82846B (0.50 g, 83.9 % potency, 0.26 mmol) and 4'-
5 chloro-4-biphenylcarboxaldehyde (98 mg, 0.45 mmol) were
stirred in 50 mL methanol and pyridine·borane complex (0.015
mL, 0.15 mmol) was added. The reaction mixture was heated
at reflux for 4 hours and an additional aliquot of
pyridine·borane complex (0.015 mL, 0.15 mmol) was added.
10 After heating at reflux for 4 hours longer a final addition
of pyridine·borane complex (0.015 mL, 0.15 mmol) was made.
The reaction mixture was heated at reflux for another 20
hours. After cooling to ambient temperature HPLC analysis
of a reaction aliquot afforded a yield of 0.27 g (58.0 %) of
15 N⁴-(4-(4-chlorophenyl)benzyl)A82846B.

EXAMPLE 3

(with copper)

20 A82846B (0.50 g, 84.3% potency, 0.42 bg, 0.26 mmol)
was stirred in 50 mL methanol and cupric acetate (45 mg,
0.25 mmol) was added. After stirring at ambient temperature
for 10 min, 4'-chloro-4-biphenylcarboxaldehyde (84 mg, 0.39
mmol) and pyridine·borane complex (0.039 mL, 0.39 mmol) were
25 added. The mixture was heated at 57° C for 24 hours before
being cooled to ambient temperature. HPLC analysis of a
reaction aliquot afforded a yield of 0.34 g (72.3%) of N⁴-
(4-(4-chlorophenyl)benzyl)A82846B.

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EXAMPLE 4

(with copper + portionwise addition of pyridine·borane)

A82846B (0.50 g, 76.3% potency, 0.38 bg, 0.24 mmol)
5 and cupric acetate monohydrate (43 mg, 0.216 mmol) were
stirred in 50 mL methanol and 4'-chloro-4-biphenylcarbox-
aldehyde (84.5 mg, 0.39 mmol) and pyridine·borane complex
(0.011 mL, 0.11 mmol) were added. The mixture was heated at
63°C for 2 hours and an additional portion of
10 pyridine·borane was added (0.01 mL, 0.1 mmol). After 2
hours more at 63°C a third portion of pyridine·borane (0.005
mL, 0.05 mmol) was added. A fourth portion of
pyridine·borane (0.005 mL, 0.05 mmol) was added 2 hours
later followed by a fifth portion of pyridine·borane (0.005
15 mL, 0.05 mmol) after another 5 hours at 63°C. The mixture
was heated at 63°C for another 11 hours before being cooled
to ambient temperature. HPLC analysis of a reaction aliquot
afforded a yield of 0.34 g (79.2%) of N⁴-(4-(4-
chlorophenyl)benzyl)A82846B.

20 The reactions reported in Examples 1, 3, and 4 were
also evaluated (1) for the amount of the remaining starting
glycopeptide, (2) for the amount of products alkylated on
amine sites other than the N⁴-position, and (3) for the
amount of multiply-alkylated products. The results are set
25 forth in the following table and are expressed as a
percentage relative to the intended product monoalkylated on
the N⁴-amine; yields of the intended product are actual
yields as recited in the foregoing examples.

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TABLE I

Ex. No.	% Mono-alkylated at N ⁴	% A82846B	% Mono-alkylated at N ⁶	% Mono-alkylated at N ¹	% Di-alkylated at both N ⁴ and N ⁶	% Di-alkylated at both N ¹ and N ⁴	% Tri-alkylated
1	53.2	47.6	9.9	1.3	21.7	7.8	1.8
3	72.3	17.8	2.1	0.7	6.2	2.5	0.4
4	79.2	9.2	1.4	0.3	7.4	3.4	0.3

These data show that portionwise addition of
 5 pyridine·borane, accompanied by the use of copper, maximizes
 yields of the product monoalkylated on N⁴, while minimizing
 yields of other alkylated products.

EXAMPLE 5

10 (with copper + portionwise addition
 of pyridine·borane by syringe pump)

A82846B (0.50 g, 83.4 % potency, 0.26 mmol) and cupric
 acetate (47 mg, 0.26 mmol) were stirred in 50 mL methanol
 15 and 4'-chloro-4-biphenylcarboxaldehyde (98 mg, 0.45 mmol)
 and pyridine·borane complex (0.015 mL, 0.15 mmol) were
 added. The reaction mixture was heated at 63°C for 2 hours.
 Additional pyridine·borane complex (0.03 mL, 0.30 mmol) in 2
 mL methanol was added to the reaction mixture at a rate of
 20 400 uL/hour using a syringe pump. The temperature was
 maintained at 63°C during the addition. After the addition
 was complete, heating was continued to afford a total
 reaction time of 24 hours. After cooling to ambient

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temperature, HPLC analysis of a reaction aliquot afforded a yield of 0.35 g (74.3 %) of N⁴-(4-(4-chlorophenyl)benzyl)A82846B.

The following HPLC System was used for *in situ* reaction monitoring and yield calculation: HPLC system Waters 600E with HP3395 integrator and Applied Biosystems 757 detector set at 230 nm, sensitivity 0.1 absorption units, 1 sec. filter rise time. Column: DuPont Zorbax SB-Phenyl, 4.6 mm x 25 cm. Eluant A: 10% acetonitrile, 90% buffer (0.2% triethylamine, 0.25% H₃PO₄). Eluant B: 60% acetonitrile, 40% buffer (0.2% triethylamine, 0.25% H₃PO₄). Gradient profile at 1 mL/min: initialize 100% A, gradient to 80% A, 20% B over 5 minutes, hold 5 minutes, gradient to 100% B over 20 minutes, gradient to 100% A over 5 minutes, hold 20 minutes. Sample preparation: 0.5 - 1.0 g of reaction mixture diluted to 25 mL in acetonitrile - buffer. Hold at ambient temperature about 30 minutes until the purple color of the copper complex is discharged. The desired glycopeptide alkylation product elutes at 16-18 minutes, the starting glycopeptide nucleus at 3-4 minutes, the site N⁶ (monosugar) alkylation product at 18-19 minutes, the site N¹ (methyl leucine) alkylation product at 19-21 minutes, dialkylated impurities at 24-26 minutes, and aldehyde at 35-36 minutes. *In situ* yield is determined by correlation to standards prepared with a reference sample of the product.

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CLAIMS

1. In a process for reductively alkylating an amine-containing glycopeptide antibiotic, which process comprises reacting the glycopeptide antibiotic with an aldehyde or
5 ketone in the presence of a reducing agent, the improvement which comprises employing pyridine-borane as reducing agent.

2. A process of Claim 1 conducted in methanol at a temperature of from 58-63°.

3. A process of Claim 1 or 2 in which the
10 glycopeptide antibiotic, aldehyde or ketone, and a portion of the reducing agent are mixed together at the same time, and one or more additional portions of reducing agent are added thereafter.

4. A process of any of Claims 1-3 in which a source
15 of soluble copper is additionally supplied.

5. A process of any of Claims 1-4 in which the glycopeptide antibiotic is vancomycin, A82846A, A82846B, A82846C, or orienticin A.

6. A process of any of Claims 1-5 in which the
20 glycopeptide antibiotic is A82846B.

7. A process of any of Claims 1-6 in which the ketone or aldehyde is 4'-chloro-4-biphenylcarboxaldehyde.

INTERNATIONAL SEARCH REPORT

 International application No.
PCT/US97/21126

A. CLASSIFICATION OF SUBJECT MATTER IPC(6) : A01N 37/18; 38/00, 38/14, 38/16 US CL : 514/2, 8, 9; 530/322, 345 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 514/2, 8, 9; 530/322, 345 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched NONE Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) APS, MEDLINE, SCISEARCH, EMBASE, WPIDS, BIOSIS, CAPLUS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	LEE et al. Efficient coupling of glycopeptides to proteins with a heterobifunctional reagent. Biochemistry. 1989, Vol. 28, pages 1856-61, see especially page 1858, left column.	1-7
Y	WONG et al. Pyridine borane as a reducing agent for proteins. Analytical Biochemistry. 1984, Vol. 139, No. 58-67, pages 58-67, see p. 65.	1-7
Y	US 4,877,450 A (BRASCH) 31 October 1989, col. 3, lines 10-30.	4
<input checked="" type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
* Special categories of cited documents:	*T* later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention *A* document defining the general state of the art which is not considered to be of particular relevance *E* earlier document published on or after the international filing date *X* document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone *L* document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) *Y* document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art *O* document referring to an oral disclosure, use, exhibition or other means *P* document published prior to the international filing date but later than the priority date claimed *A* document member of the same patent family	
Date of the actual completion of the international search 11 FEBRUARY 1998		Date of mailing of the international search report 19 MAR 1998
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230		Authorized officer SUSAN HANLEY Telephone No. (703) 308-0196

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US97/21126

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	COOPER et al. Reductive alkylation of glycopeptide antibiotics: synthesis and antibacterial activity. J. Antibiotics. June 1996, Vol. 49, No. 6, pages 575-581, see page 476.	1-7
Y	NAGARAJAN et al. Synthesis and antibacterial evaluation of N-alkyl vancomycins. J. Antibiotics. January 1989, Vol. 42, No. 1, pages 63-72, see page 63.	1-7
Y	TATTANAHALLI et al. The synthesis of netilmicin via complexing of vicinal and non-vicinal amino-hydroxyl group pairs with divalent transition-metal cations. Carbohydrate Research. 1984, Vol. 130, pages 243-249, see page 244.	1-7